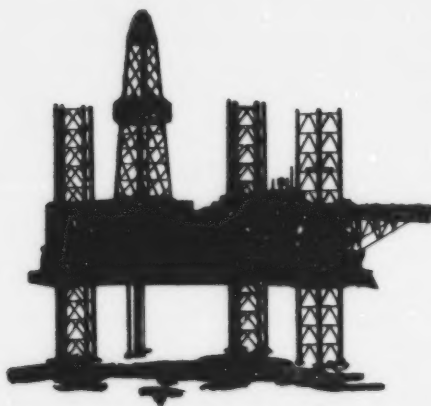


AN INTRODUCTION TO THE OFFSHORE



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Overview

As the petroleum industry broadened its search for petroleum to new areas during the latter part of the 1950s, the Continental Shelf off Nova Scotia or Scotian Shelf, came to be considered a promising and exciting prospect. In 1959, Mobil Oil undertook an air magnetometer¹ survey of the Sable Island area, the first petroleum exploration activity to occur offshore Nova Scotia. The first well (Mobil Sable Island C-67) was drilled on Sable Island in 1967. This was followed in September 1969 by the first of a series of wells drilled for Shell Canada Limited by the semi-submersible drilling unit, Sedneth 1. By early 1985 more than 102 wells had been drilled in Nova Scotia's offshore. (Figure 1)

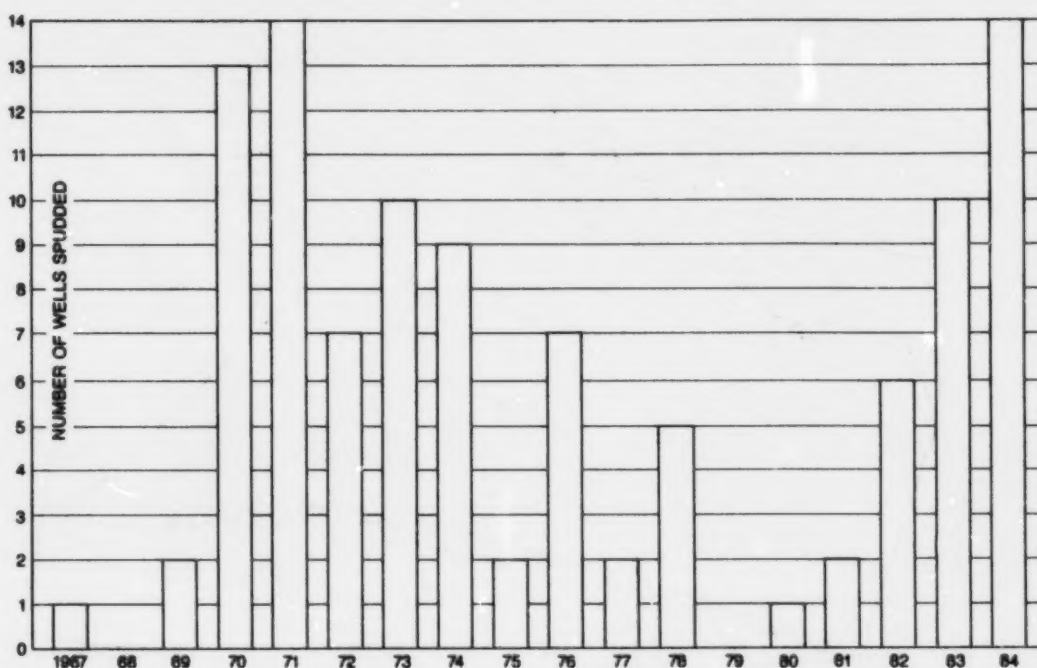


Figure 1. Drilling Activity Offshore Nova Scotia 1967-1984.

To date, major national and international oil companies, including Mobil Oil, Husky-Bow Valley, Home Oil, Murphy, Petro-Canada, Shell and Union have all undertaken exploration programs. A number of these companies are presently continuing their exploration efforts offshore.

¹ Magnetometer and other terms commonly used in the offshore oil and gas industry are defined in the Glossary.

As of early 1985, twelve significant natural gas discoveries and three significant oil-bearing structures have been discovered. Four natural gas discoveries made by wildcat (exploration) wells in late 1983 and early 1984 on previously unexplored structures are the newest discoveries to be classed as significant. Planning for the development of the Venture gas field off Sable Island - the first offshore Nova Scotia discovery from which commercial production is anticipated - is well advanced. Development of other fields is expected to be tied into the Venture field, resulting in a multi-field development project.

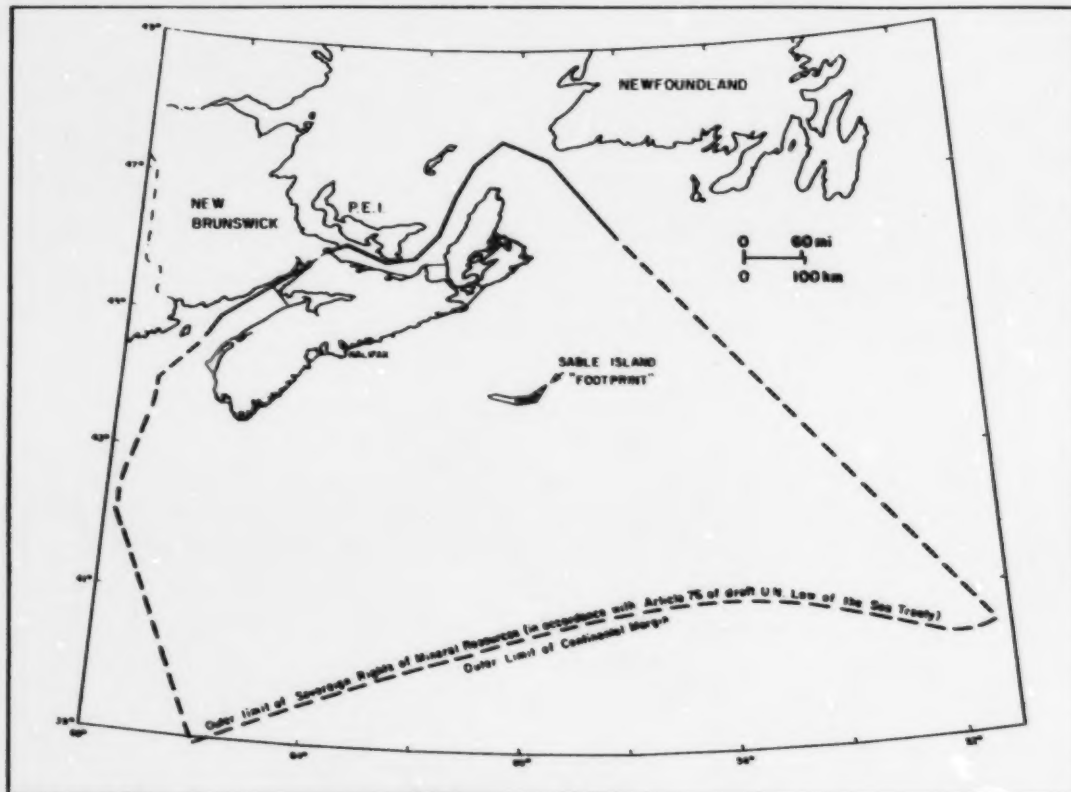


Figure 2 Nova Scotia Offshore and Onshore Region.

The Government of Nova Scotia and the Government of Canada jointly manage petroleum related exploration and development in Nova Scotia's offshore region, the Province through the Department of Mines and Energy and the federal government through the Canada Oil and Gas Lands Administration (COGLA). Both governments enacted legislation in 1984 to

govern petroleum related activity in the offshore region. In addition, the Province amended several statutes pertaining to petroleum related activity onshore.

The Nova Scotia legislation consists of three offshore and four onshore acts. Several of these statutes legally implement provisions of the Canada-Nova Scotia Agreement on Offshore Resource Management and Revenue Sharing signed in March 1982. The legislation, as a whole, provides a framework for the orderly exploration, development and production of Nova Scotia's offshore and onshore petroleum resources. The offshore and onshore regions to which this legislation applies are shown in Figure 2.

Origin and Accumulation of Oil and Gas

Petroleum derives its name from the Latin "petra" meaning rock and the Latin "oleum" meaning oil. In general, petroleum is a complex mixture of hydrogen and carbon with traces of other elements. It includes natural gas, crude oil and bitumen. These are also frequently called hydrocarbons because they are composed of hydrogen and carbon atoms.

Most petroleum geologists believe that oil and gas originated from organic matter of both plant and animal origin that accumulated in fine-grained sediments under quiet conditions relatively deficient in oxygen.

When plant and animal organisms that lived in the oceans died, these organisms drifted to the ocean floor and were buried under layer upon layer of silt, mud and sand. These sediments became compressed over time. Eventually mud became shale; sand became sandstone; and shells became limestone, known collectively as sedimentary rock. As the seas receded and the land mass took form, the decaying marine life was buried deeper and held captive beneath the accumulating layers. It is thought a combination of bacterial action, heat and pressure produced petroleum from the decaying organic material. Far below the earth's surface, rock layers buckled and shifted and the petroleum became trapped under a mass of non-porous impenetrable rock.

To be recoverable, hydrocarbons must leave their miniscule state in the fine grained source rocks and move into porous sedimentary rocks (reservoirs), where they collect and can be withdrawn through drilled wells. Contrary to popular belief, oil does not exist underground in pools or lakes but is found in the pore spaces of rock. The way the hydrocarbons migrate to the pore spaces is largely unknown. What is known is that the movement is aided by the presence of water (usually salt water) in the sediments and by compaction (squeezing) - the result of the great weight of the overlying rocks.

The movement of hydrocarbons into a porous reservoir is, however, only the first step. The migration continues in the porous formation until the gas or oil escapes to the surface (as at the Athabasca tar sand in Alberta) or is retained below by some subsurface barrier called a trap. The shapes and styles of traps are many but are usually related to the geological history of any particular area (Figure 3).

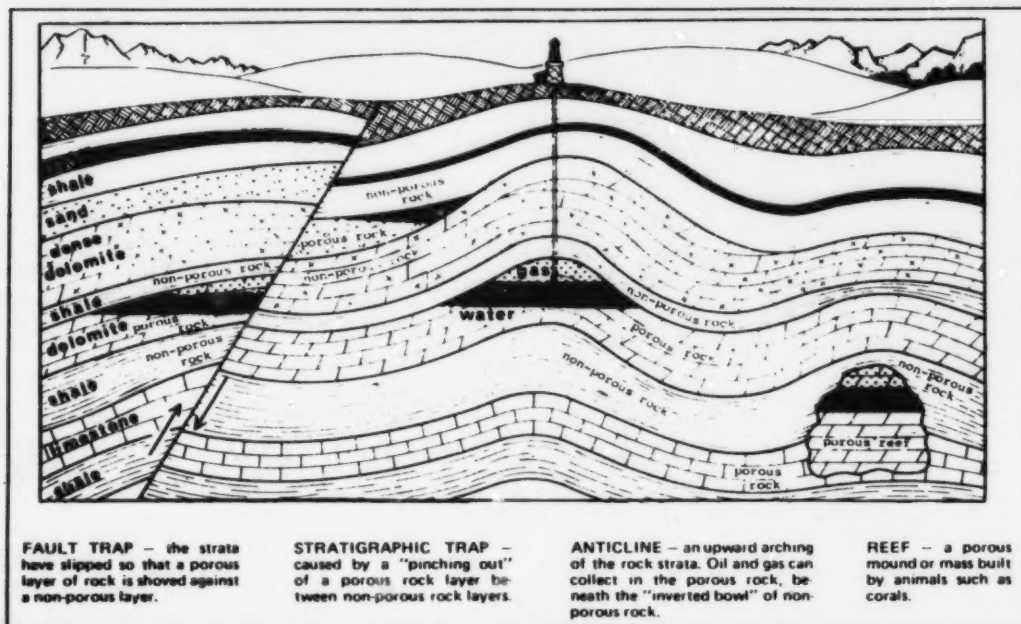


Figure 3 Geological Traps for Hydrocarbons.

The common element in all traps is that further migration or flushing (by water) of the hydrocarbons toward the surface is prevented by overlying impermeable formations - as an inverted dish will retain air when immersed in water. A further requirement of the trap is that it be preserved. Trapped oil and gas can be lost by faulting. It is very possible that more oil and gas have been "lost" during geological time than have been preserved in traps discovered thus far.

Geology of the Scotian Shelf

The offshore areas of Nova Scotia with sediments of sufficient thickness to produce hydrocarbons are extensive and surround the Province. On the Scotian Shelf, these sediments extend seaward for more than 320 km.

The Scotian Shelf is one of Canada's largest sedimentary basins. Sediments capable of producing hydrocarbons are found throughout the Shelf. The greatest thicknesses of sediments were deposited in the Sable Island and Abenaki sub-basins and it is here the majority of oil and gas discoveries, including Venture, are located on the Scotian Shelf (Figure 4).

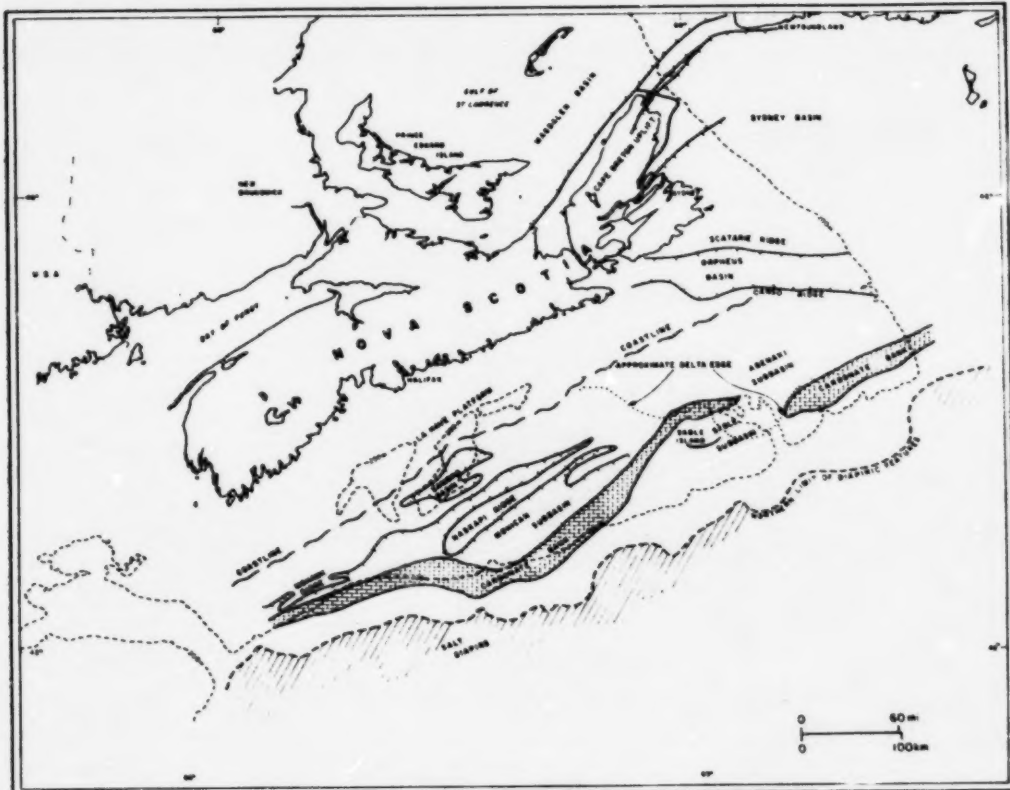


Figure 4 Physiographic features of Scotian Shelf at Lower Cretaceous Time.

Generally, the Scotian Shelf contains thick sequences of mudstone, sandstone, shale, chalk and limestone that vary in thickness and depositional characteristics. Geophysical surveys indicate the Sable Island sub-basin may contain a thickness of sediment of up to 12 000 metres. The deepest well drilled to date on the Scotian Shelf is Petro-Canada's Banquereau S.W. F-34 that bottomed in shale at 6 309 metres (Figure 5).

In its natural state, oil and gas always exist at a pressure greater than atmospheric, a condition which, when trapped, forces the liquid and gases to flow upwards. The use of this natural condition to recover petroleum from a well is called "primary recovery". The rate at which hydrocarbons move through the rock towards the well bore depends on the reservoir pressure, the pressure at the bottom of the well, the permeability of the rock and the viscosity of the gas and/or oil. As the gas and/or oil is removed from the rock, the pressure of the reservoir decreases and the rate of production declines unless the pressure is sustained. The producer must then turn to artificial methods to restore reservoir pressure. This "secondary" or enhanced recovery is accomplished by injecting water, natural gas or chemicals into the reservoir to force the petroleum through the rock and out the well bore.

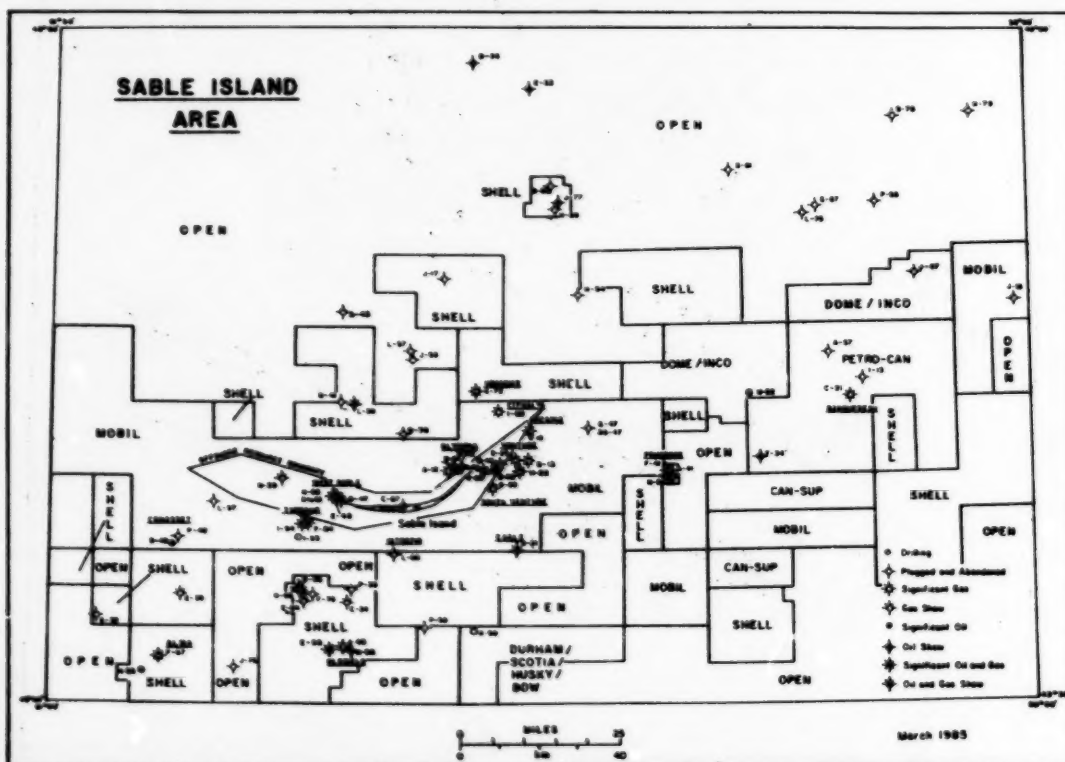


Figure 5 Wells Drilled in the Sable Island Area

Exploration Procedures

Oil and gas is found beneath the ocean in reservoirs similar to those onshore. The search for petroleum begins with geology and geophysics. Geologists and geophysicists look for certain rock types and formations as evidence of the presence of oil and gas.

Seismic is used to obtain a picture of the rock formations below the surface. Sound waves created by explosions from an air gun (towed behind a survey vessel) are bounced off the layers of rock under the ocean floor and resulting reflections are picked up by sophisticated receivers called hydrophones towed behind the survey vessel (Figure 6). The information obtained indicates the shape of the undersea geological formations. Geophysicists analyze this data to see if the structures are capable of containing oil or gas.

A profile is put together from the individual recordings that show the rock layers and their deformation by folding, faulting or piercement by salt or shale intrusions. By using a grid or network of these profiles and by following a specific reflection, a contour map of the subsurface structure can be constructed in much the same way as a topographic map of the earth is made.

Such maps indicate structural domes, anticlines, faults and other features that could form traps for hydrocarbons. The actual depths at which these maps are made may vary from 100 to more than 6 000 metres below the surface, depending on the thickness and the response to the sound waves from the column of sedimentary rocks and the estimated depth to potential oil and/or gas bearing formations.

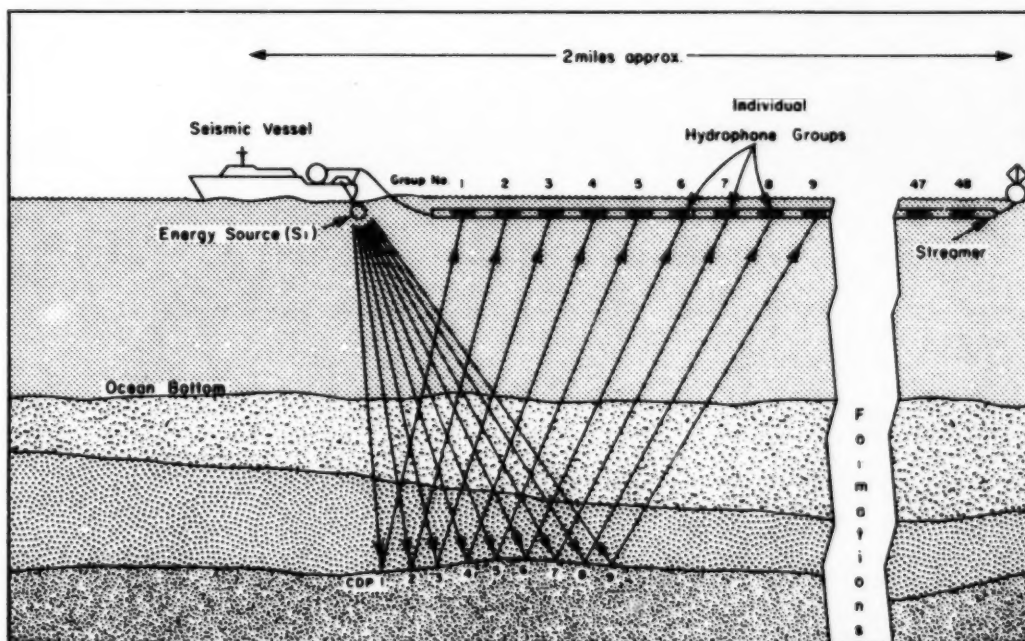


Figure 6 Diagram of Typical Geophysical Survey.

It is necessary to know the exact surface positions from which all the recordings are made so that well locations can be accurately selected. Radio positioning from known stations on shore or from earth satellites are used to map the location of seismic recordings.

Drilling Procedures

A structure identified on a seismic profile may have all the characteristics that geologists and geophysicists look for in a good reservoir. But the only way to really know if it contains oil or gas is to drill a well. Once a drilling location is determined, a drilling contractor is found with equipment suitable for the particular water conditions and proposed depth of the hole (Figure 7).

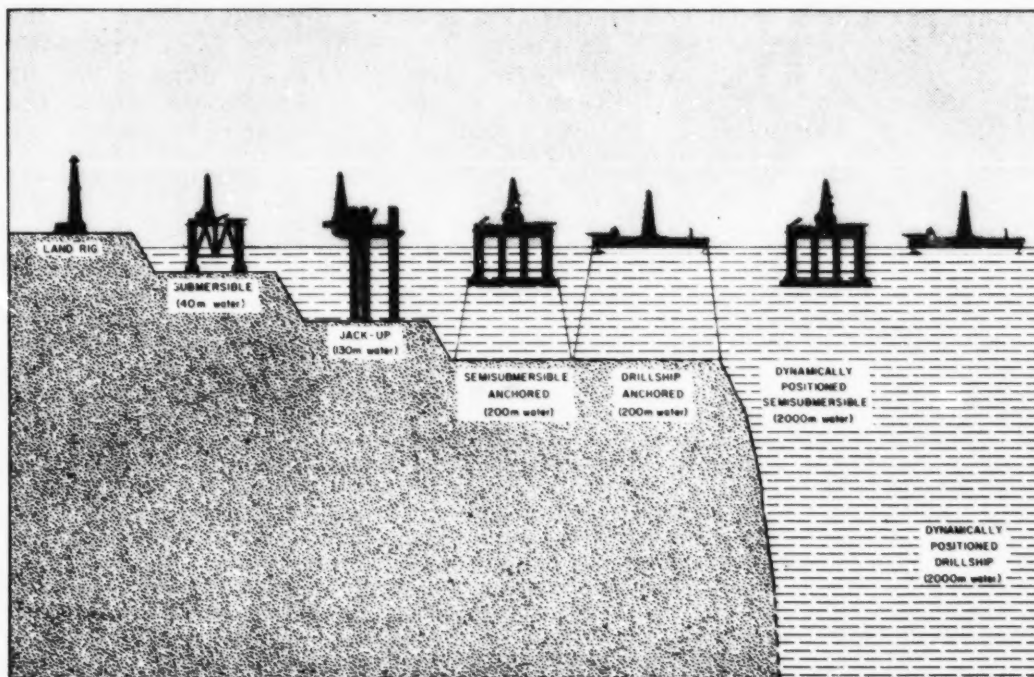


Figure 7 Types of Drilling Units.

If the well is located in relatively shallow water, a jack-up drilling rig may be used. Jack-up drilling rigs are in common use off Nova Scotia. The jack-up drilling rig is floated to the site, and its legs lowered so that it sits on

the seafloor and only its drilling deck and equipment are above the waves. Because a jack-up actually sits on the seafloor, the depth in which it is used is generally limited to 130 metres.

In deeper waters, the drilling contractor uses drill ships or semi-submersible drilling rigs. Semi-submersible drilling rigs, rather than drillships, are used in the deeper waters off Nova Scotia. A semi-submersible displaces as much as 50,000 tonnes of water and may equal a battleship in weight. To operate, it is moved into position and held in place by anchors or by computer controlled thrusters. The hull is then submerged so that part of the vessel sinks below the surface while the drilling deck remains above the water line. Since only a few columns emerge above the water line, the impact of hostile winds and waves is minimized.

Drilling an exploration and/or production well five or six kilometres below the seabed may take six to nine months, depending on well depth and conditions encountered. A typical well drilled to 5 486 metres using a semi-submersible rig costs in the range of \$50-\$60 million in 1984 funds (Figure 8).

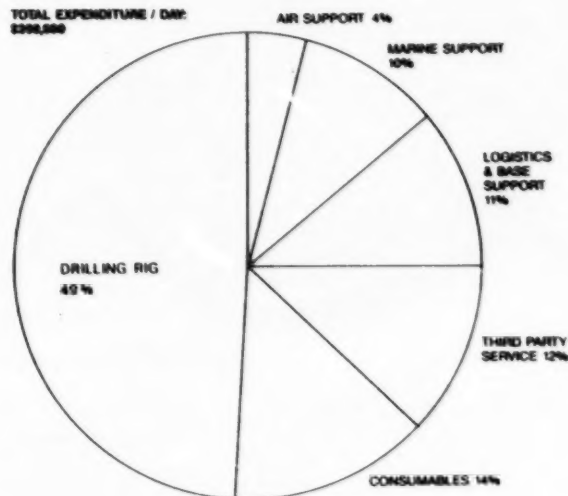


Figure 8 Average Offshore Well Expenditures.

Once the drilling vessel is in position, drilling operations can begin. All wells in the offshore are drilled with rotary rigs. Rotary rigs use electric motors or diesel engines to rotate a long string of drill pipe. The drill bit at the end of the string cuts and grinds through the rock. It can wear out after only hours if layers of extremely hard rock are encountered. As drilling progresses, the well is lined with steel casing cemented to the sides of the hole.

Casing is important as it helps prevent rock from crumbling into the hole and is designed to contain high pressure gases and liquids, helping to prevent dangerous blowouts. Casing also serves as part of the circulatory system for drilling mud used to lubricate the bit and flush rock fragments from the hole. If the well is successful, the casing becomes part of the system used to bring oil and gas to the surface.

During the drilling operation, a continuous evaluation of the stratigraphy or rock formations encountered is carried out. Samples and cuttings brought to the surface in the drilling mud and various logs and analyses are used to obtain information on the exact nature of the stratigraphy penetrated during drilling.

If a well is deemed to be a discovery, additional delineation wells are drilled to define the magnitude of the reservoir structure. Of prime importance is information on the relative locations of hydrocarbons and water within the reservoir. Additional chemical and physical data is required to define the total amount of production expected and the most effective locations for production wells. Studies are conducted to determine the number of wells the reservoir will support, their spacing, and the required production infrastructure. For example, due to the location of the Venture D-23 discovery well in the Venture field, four additional delineation wells were required to provide better information as to the field orientation and size, as well as depths to productive zones (Figure 9).

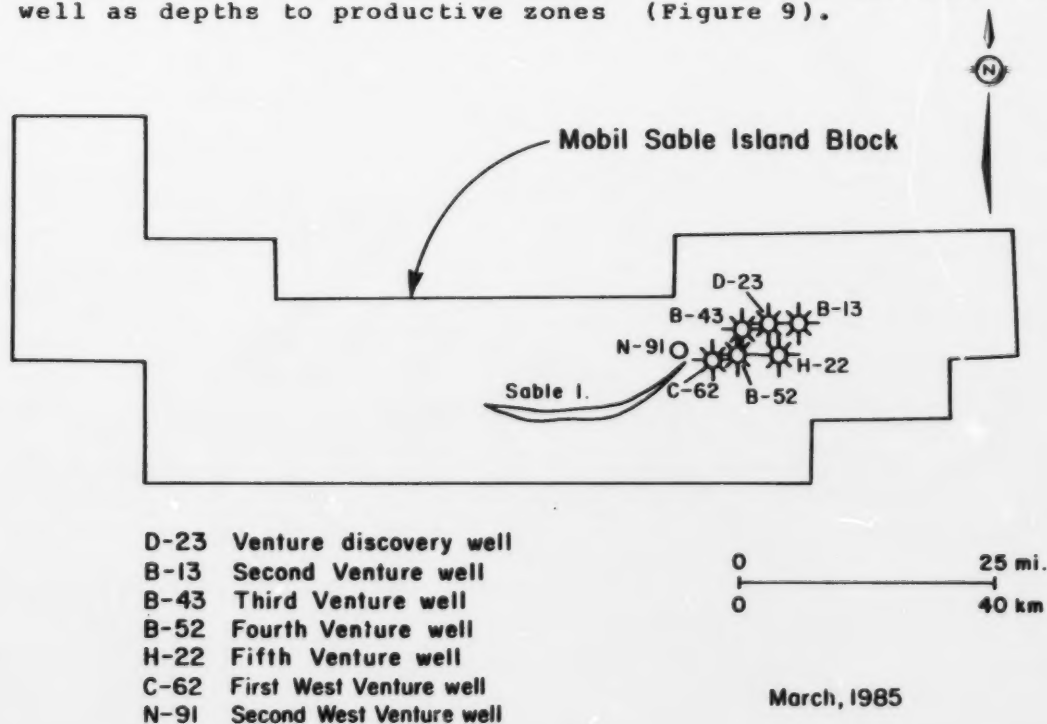


Figure 9 Venture Area Well Locations

Development - The Venture Project

Mobil Oil Canada Ltd. and its partners in the Venture project are currently planning for the development of Nova Scotia's first offshore natural gas production at an estimated cost of more than 2.5 billion in 1984 dollars. This cost includes development wells, the offshore production facilities, the pipeline to shore, the onshore pipeline to the gas plant, and the gas plant.

The natural gas is situated in the Venture field, located 16 kilometres east of the eastern end of Sable Island and approximately 200 kilometres from the coast of mainland Nova Scotia (Figure 10). The Venture field covers an area of 2 800 hectares. The water depth is approximately 22 metres. Recoverable natural gas reserves in the field are estimated to be about 57 to 85 billion m³ of raw gas. Venture natural gas is largely found in sandstones below 4 877 metres and at extremely high pressure.

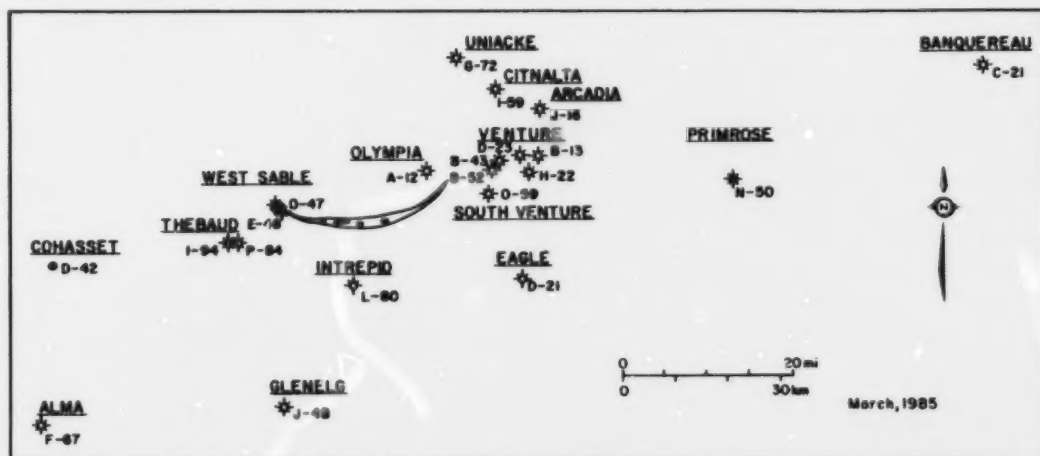


Figure 10 Map of Significant Hydrocarbon Discoveries

The gas from the Sable Island area is typically "sweet gas" which means it is fortunately not contaminated with hydrogen sulfide. (Figure 11) Gas with this compound, called "sour gas" is found in many Western Canadian gas deposits, and is highly corrosive and creates additional expenses and difficulties in processing and transportation.

Natural Gas	Methane	89%
	Ethane	5%
	Propane	1%
Natural Gas Liquids	Butane	1%
	Condensate	2%
Contaminants	Nitrogen, CO ₂ , etc.	2%

Figure 11 Representative Analysis of Fluid Recovery from Sable Area

The significant amount of condensate associated with the Scotian Shelf hydrocarbons is an added bonus in that it provides the basis for other marketable products.

The designs for offshore facilities needed to produce Venture gas are changing as new seismic data and drilling results from appraisal wells provide additional information about the extent of the Venture gas reservoir. The offshore production facilities required to produce natural gas from the shallow waters of the Scotian Shelf near Sable Island will be similar to those used in the southern North Sea.

Self-contained offshore platform complexes will be required to produce Venture natural gas. A typical production system may consist of a central facility with three steel-jacketed structures: a combination wellhead and production platform, an accommodation platform and a flare structure. The remaining two complexes may be smaller and each may consist of two structures: an integrated wellhead, production and accommodation platform, and a flare structure.

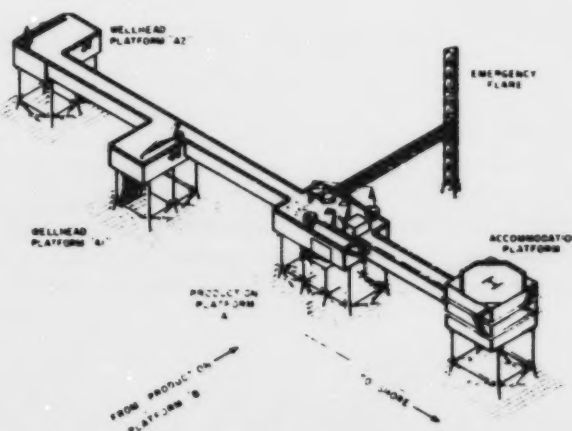


Figure 12 Offshore Production Complex

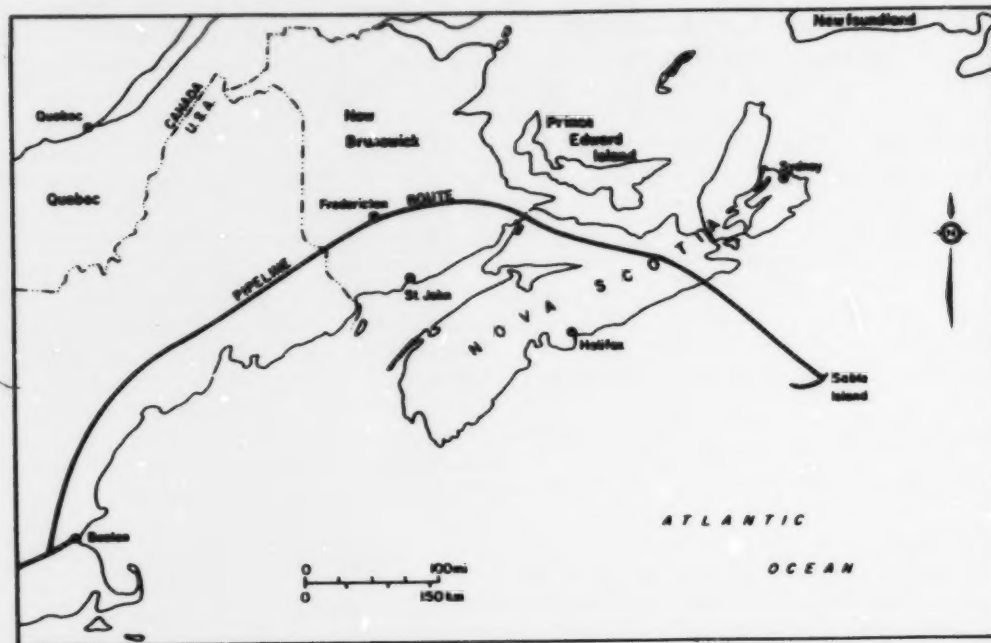


Figure 13 Map of Pipeline Route from Sable Island

It is estimated that approximately 20 development wells will be required to produce from Venture the required volume of gas necessary to operate an offshore facility.

The offshore processing will primarily consist of dehydration and sand removal on the production platforms prior to delivery of the gas to the offshore pipeline. In later years, compressor facilities will be required to maintain pipeline pressure as the natural reservoir pressure declines.

Plans call for the gas and natural gas liquids to be transported from the offshore complexes to shore in a 762 millimetre diameter pipeline along a route approximately 265 kilometres long. It is proposed that the landfall site will be in eastern mainland Nova Scotia. Landfall facilities will include a slug-catcher to receive and separate the slugs of liquid that form in the pipeline.

Once onshore, the gas will be processed at a conditioning plant yielding "sales gas" and "natural gas" liquids. The liquids will be further processed into saleable propane, butane and condensate products. The liquid products will be stored at the onshore processing plant and transported to market by truck, rail and from the marine terminal, by tanker.

Once processed onshore, the sales gas will be transported to markets in Canada and the United States through a "transmission" pipeline across Nova Scotia and New Brunswick to the United States border (Figure 13). The transmission system requires large diameter underground pipes to transport the gas. The transmission system also includes "laterals", which are smaller diameter lines carrying gas from the main transmission line to various points called "city-gates", where the pipeline connects with the "distribution system". The distribution mains are generally placed under city and town streets with "tie ins" from the street to gas meters at individual homes, factories, or business locations. The "conversion phase" takes place inside the house, factory or business establishment where the gas is ultimately consumed (Figure 14).

Construction of the transmission and distribution system will mean the investment of more than one billion dollars over and above the cost of the Venture project itself.

The activity generated by oil and gas exploration expands the opportunities available to both business and individuals in Nova Scotia. The Province of Nova Scotia is working with the petroleum industry and the federal government to ensure orderly and safe exploration and development of our offshore petroleum resources for the optimum economic and social benefit of Nova Scotia.

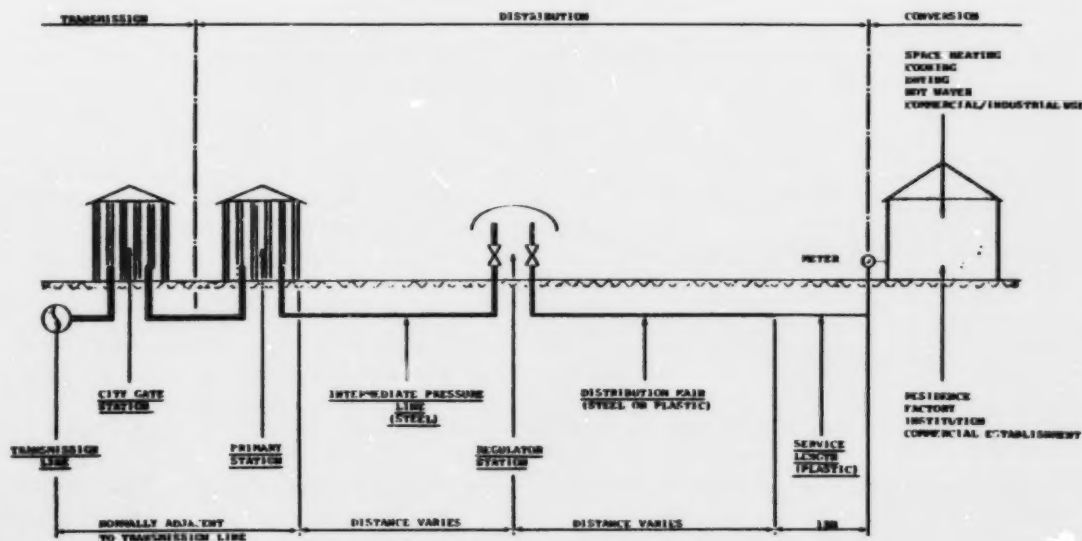


Figure 14 Design of Gas System Components

GLOSSARY

Appraisal well: A hole drilled close to another that has been shown to have oil or gas producing potential in order to gain more information about a reservoir. As an appraisal well is drilled to gain more information about a field, so step-out or delineation wells are special kinds of appraisal well.

Butane: A member of the alkane group of hydrocarbons and a natural constituent of petroleum. It is a colourless, flammable, wet gas at normal temperature and pressure, but is easily liquefied.

Condensate: A natural gas liquid with a low vapour pressure compared with natural gasoline and liquefied petroleum gas. It is produced from a deep well where the temperature and pressure are high. Gas condenses as it rises up the well bore and reaches the surface as condensate. Similarly, condensate separates out naturally in pipelines or in a separation plant by the normal process of condensation.

Crude oil: A liquid mixture of many substances, chiefly compounds of hydrogen and carbon.

Delineation well: An exploration well drilled as part of a carefully planned program with the object of appraising the value of an oil or gas discovery. Delineation wells, or step-out wells, are drilled so that the probable outline of the oil or gas-field may be delineated.

Development drilling: Extension of a drilling program once a strike has been established and proved to be capable of economic production. Development wells, which may be vertical wells or deviated wells, are usually drilled from permanent platforms. Some development wells may be production wells, others injection wells, so their number and location depends on the extent of the field and the drive mechanism employed.

Deviated well: A well drilled at an oblique angle, usually from a production platform, and which consequently enters the producing horizon a calculated distance away from the main vertically drilled well. It is possible to drill wells which diverge as much as 60° from the vertical. A well bore may also be deviated deliberately to avoid an obstacle. This is known as side tracking. A directional hole is another name for a deviated well.

Discovery well: An exploration well which shows evidence of oil or gas where no previous show had been recorded.

Disposal well: A well drilled for the specific purpose of re-injecting produced salt water back into a reservoir, such wells may also be employed in a secondary recovery process.

Drilling unit: In the field of offshore drilling, a drilling unit refers to a bottom-supported structure, such as a jack-up drilling unit, or a floater, such as a drillship or a semi-submersible drilling unit. The term also describes a drilling rig.

Gas: 1. A substance which has neither independent shape nor volume, and whose physical state is such that it always occupies the whole of the space in which it is contained.
2. The popular term for gasoline in Canada.

Gaseous petroleum: The lighter hydrocarbons, including the dry natural gases (methane and ethane) and the wet gases (butane and propane).

Gas-field: A group of reservoirs of hydrocarbons associated with a common geological structure, where the gas-oil ratio is high and production is commercially viable. The size of a gas-field is judged by the size of its recoverable reserves, measured in trillions of cubic feet, or millions of cubic metres.

Liquefied natural gas: LNG is natural gas which has been liquefied for transportation by cooling to cryogenic temperatures. LNG is converted so that it can be easily transported and then regasified before distribution. Natural gas occupies 635 times the volume of LNG before it is liquefied.

Liquefied petroleum gas: Gas with a high vapour pressure, which has been moderately compressed and cooled to separate C_3 and C_4 hydrocarbons. LPG consists mainly of butane and propane, with small proportions of heavier hydrocarbons, and is obtainable from wet gas by cracking crude oil, or from refinery gases.

Log: A permanent record of events. In offshore drilling technology numerous logs are maintained to record events happening downhole and on the surface during drilling operations. The range of logs used is extensive and only some of them are kept continuously, others being run as required to meet certain situations.

Logging: The action of permanently recording activities, occurrences and measurements during a drilling programme, whether automatically by electronic means, or in narrative form. Many logs are used as tools in formulating and assessment of likely producing capabilities of a structure, others are essential to safe and efficient drilling operations, and all become stores of experience to support future exploration ventures.

Magnetometer: An instrument for measuring the intensity and direction of magnetic forces. Data obtained is sometimes used with gravity and seismic data.

Magnetometer Survey or Magnetic Survey: A geological survey which compares the magnetic properties of overlying rocks with those of base rocks. Scientists (knowing that sedimentary rocks are virtually non-magnetic and base rocks contain iron) and are able to deduct the presence and thickness of sedimentary deposits in the area.

Natural gas: A mixture of gaseous hydrocarbons found in many kinds of sedimentary rock and closely related to crude oil, differing from it mainly in the range of hydrocarbons in its constitution.

Natural gas liquids: The components of natural gas which are liquid at normal pressure and temperature, and can easily be extracted in liquid form. Natural gas liquids can be classified according to their vapour pressures, as low, intermediate and high vapour pressure liquids, or condensate, natural gasoline and liquefied petroleum gas, respectively.

Natural gasoline: A natural gas liquid having a vapour pressure intermediate between that of condensate and liquefied petroleum gas.

Permeability: The rate at which fluid will flow through the pore spaces of a rock due to an external pressure. In oil production the degree of permeability of a reservoir determines the production rate. Rocks of high permeability usually have high porosity but permeability depends upon the shape and size of the pore spaces.

Primary recovery: Using natural forces to drive oil or gas from a reservoir to the surface of a well bore. It is also known as the flush phase of oil or gas production, or natural depletion.

Raw natural gas: Natural gas containing water and other unwanted substances and impurities, such as nitrogen, carbon dioxide, hydrogen sulphide gas and helium. These are removed before a natural gas can be considered marketable.

Sales gas: Methane and ethane with up to three per cent carbon dioxide, or raw gas after processing to remove LPG, condensate and carbon dioxide.

Secondary recovery: Techniques practiced to extend the life of a well after flow under natural pressure has declined. Primary recovery may succeed in bringing only 25 per cent of available oil to the surface and secondary recovery may produce a further 15 to 25 per cent of "second crop" oil. Additional wells may have to be sunk to inject water or gas to re-pressure the drive, if such a scheme did not form part of the primary recovery plan.

Sour gas: An acid gas containing a significant amount of hydrogen sulfide. Natural gas with more than 1.5 grains of hydrogen sulphide per 100 cubic feet is sour gas.

Sweet gas: Natural gas containing only very small amounts of hydrogen sulphide gas and carbon dioxide. Sweet gas is desirable in the interests of reducing the concentration of sulphur dioxide in the atmosphere, and inhibiting corrosion, so any sour gas is first treated, for example, with triethanolamine to remove the undesirable elements before being passed to the consumer. Most North Sea and Scotian Shelf gas is considered to be naturally sweet.

Tertiary recovery: Known as "third crop" production. Recovery of hydrocarbons from a field after first primary, then secondary production phases have ended. Techniques are similar to those used in secondary recovery, but are more drastic. They involve chemical and thermal agitation, and hydraulic fracturing, as well as gas and water injection. At best a further 25 per cent of oil or gas in the reservoir may be recovered. Stripping is regarded as a passive form of "third crop" production.

Third crop production: Production of oil or gas from a field after applying tertiary recovery methods to stimulate oil or gas flow.

Viscosity: The property of a liquid or semi-liquid to resist flow, due to the mutual attraction of its molecules.

Well: A borehole that produces, or is capable of producing, hydrocarbons. The term is often used loosely to describe any borehole but wells may be classified into six categories. These are, new field and new pool wildcat wells, shallow pool and deeper pool test wells, outpost wells and development wells. A wildcat well or an exploration well is drilled in new territory; appraisal, confirmation, step-out, and delineation wells are drilled for the purpose of evaluating a field. Wells drilled from a production platform are development wells and may be deviated wells. Wells drilled for the purpose of injecting water or gas are called re-injection wells.

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